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Chapter

Antimicrobial and Antioxidant Potential of Wild Edible Mushrooms

Maria Paula Gómez Román, Nathalia Badillo Mantilla, Sergio Andrés Carreño Flórez, Surajit De Mandal, Ajit Kumar Passari, Beatriz Ruiz-Villáfan, Romina Rodríguez-Sanoja and Sergio Sánchez

Abstract

Wild edible mushrooms have a high nutritional property that has been consumed by people from different parts of the world, producing a wide variety of bioactive compounds such as polysaccharides, peptides, glycoproteins, triterpenoids, lipids, and their derivatives. In the world, multidrug-resistant pathogens have been increasing drastically, and it is very urgent to search for alternative solutions to fight against multidrug-resistant pathogens. Moreover, unhealthy foods, ultraviolet radiation, as well as other environmental effects, are responsible for generating free radicals, oxidative stress, and numerous health diseases. Hence, the wild edible mushroom could be an alternative source of new antimicrobial potential and possesses antioxidant properties that can play significant roles in preventing various health diseases. In this book chapter, we focus on investigating the antimicrobial and antioxidant potential of wild edible mushrooms and their bioactive compound production.

Keywords: edible mushrooms, antimicrobial, antioxidant, bioactive compounds

1. Introduction

Fungi are eukaryotic and spore-bearing organisms with a life cycle divided into two phases: a growth phase and a reproductive phase. Macro fungi or mushrooms are species with a natural fruit body that can grow large enough to be visible or can grow underground. The spores, produced by the fruiting body, are the unit of sexual and asexual reproduction and are responsible for fungi's spread [1].

About 14,000 mushroom species have been reported, among them, 2000 mushrooms are reported as edible [2]. Additionally, less than 1% of the recognized fungus is poisonous, and a less percentage is fatal species [3]. Edible mushrooms have high medicinal properties due to their great rich content of polysaccharides, especially β-glucans. Many researchers reported that edible mushrooms have enormous features, including antioxidants, cholesterol-lowering properties, anti-hypertensive, anti-inflammatory, liver protection, as well as anti-diabetic, anti-viral, and anti-microbial potential (**Figure 1**) [4–7].

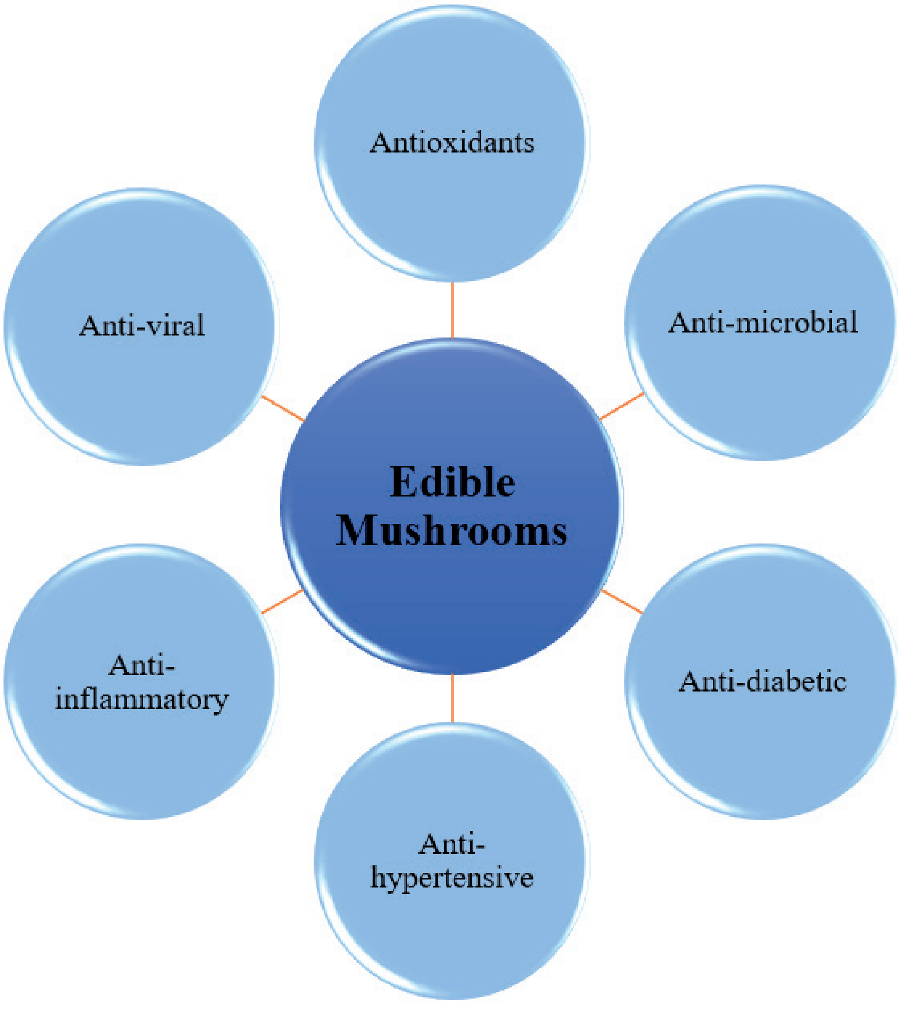

Figure 1.
Properties of edible mushrooms.

Currently, antimicrobial drug resistance is the serious problem in the world. The selection of bacterial strains based on physiological or biological aspects used high doses for the treatment of antimicrobial resistance pathogens [8]. Under certain conditions, the susceptible bacterial growth is inhibited by the drug while it becomes high resistant [9]. This problem has eagerly vigored the researchers to find the alternative source to fight against multidrug resistant pathogens and develop the new antimicrobial substances from various sources [10]. Hence, the researchers are studied that various types of mushroom have high antimicrobial potential and could be useful for new therapeutic activities such as anticarcinogenic, immuno-suppressor, and antibiotic, among others. In recent periods, different genus mushroom (*Lycoperdon* sp., *Cantharellus* sp., *Agaricus* sp., *Clavaria* sp., and *Pleurotus* sp.) extracts showing great interest as an alternative source to obtain natural products from the various researchers [11]. Various solvents like methanol, acetone and hexane was used to prepare mushroom extracts that showed significant antimicrobial activities [12, 13]. Edible mushrooms have been used in health care for treating diseases for their compelling bioactive compound content. The most widely cultivated mushrooms are *Agaricus bisporus*, *Lentinus edodes*, *Pleurotus* spp., and *Flammulina velutipes* [14], which showed the most considerable antimicrobial activity against Gram-positive and Gram-negative bacteria. Thus, it is essential to be a focus on studying different types of edible mushroom extracts to find a source of physiologically beneficial and non-toxic medicines against the multidrug-resistant pathogens [12].

Moreover, full edible mushrooms show significant antioxidant activity. Antioxidant compounds protect the cells from oxidative stress, a cellular process involved in the development of different humans' diseases as diabetic disease, Alzheimer's disease, and cancer, among others. Hence, it is necessary to investigate the different extracts of mushroom displayed potent antioxidant activity. For example, *Melanoleuca* species could be considered for pharmacological studies because of its high antioxidant capacity [15]. Additionally, a few researchers suggested that higher content of antioxidants present in the mushroom could be used as a food supplement that can supply high nutrient ability in the body [16, 17].

As we know, edible mushrooms have wide range of industrial and pharmaceutical applications. In this chapter, we will focus to describe the importance of wild edible mushrooms with their antimicrobial potential against pathogens as well as determine their antioxidant activities.

2. General information about mushroom

Mushrooms are eukaryotic heterotrophic organisms defined as macrofungi with a fruiting body formed by a cap and a stalk [18]. These macrofungi contain a wide variety of species belonging to the class Basidiomycota [19]. The mushrooms are filamentous fungi with both sexual and asexual reproduction cycle. The characteristic of basidiomycetes is a spore-producing structure or fruiting body called basidium. The morphological unit of the basidium is the hyphae, and a mass of hyphae is called mycelium. The spores produced inside the basidium are called basidiospore and are responsible for its reproduction and its dissemination. Sexual reproduction begins when the basidiospore germinates and grown as a haploid mycelium in optimal environmental conditions [1, 20]. Mushrooms are well-known as edible and non-edible macro-fungi. The edible and non-edible mushroom can differentiate based on morphological characteristics like color, appearance, and shape of the cap [3].

In recent years, many studies have been reported that mushroom has extreme nutritional properties like vitamins, fats, proteins, etc. and could have high therapeutic properties that can be used as an antioxidant, anticancer, antidiabetic, cardiovascular protector, and hepatoprotective effects [19]. Moreover, the mushroom could be used as potential sources to obtain peptides, vitamins, proteins, lipids, amino acids, fiber, and antimicrobial compounds [14]. Last 20 years, most of the food industry could use the mushroom as a food product to prepare different kinds of jam, pickle, sweets, etc. [21].

3. Antimicrobial potential of edible mushroom

The use of antibiotics is the single most crucial factor leading to increased resistance of pathogenic microorganisms around the world [22]. Antibiotics are among the most commonly prescribed drugs used in human medicine. However, up to 50% of all the antibiotics prescribed for people are not needed or not optimally effective as prescribed [23]. Another major factor in the growth of antibiotic resistance is spread of the resistant strains of bacteria from person to person, or from the non-human sources in the environment, including food [24]. Natural resources have been taken advantage over the years, and among them, wild edible mushrooms vast diversity of active compounds with nutritional and antimicrobials properties [25–27]. Mushrooms have long been playing an essential role in several aspects, having medicinal value; mushrooms have been playing an indispensable role in several aspects of human activity, like feed and medicinal properties [28, 29]. Current researches have been focused on searching for new antimicrobials therapeutically potential compounds of edible mushrooms [22] recognizing that some of these molecules have health beneficial effects, including antimicrobial properties.

Mushroom	Extracts	Activity against	Method	References
Boletus lupinus; Flammulina velutipes, Phellinus igniarius, Sarcodon imbricatus, Tricholoma aurantium, Xerocomus ichnussanus	Methanol	*Escherichia coli*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Bacillus pumilus*, *Sarcina lutea*, and *Bacillus subtilis*	MIC = 2.5–50 mg/mL	Nikolovska et al. [33]
Pleurotus eryngii	Sulphated polysaccharides and crude polysaccharides	*Staphylococcus aureus*, *Listeria monocytogenes*, and *Escherichia coli*	MIC = 0.625–10.0 mg/mL and IZ = 11.7–31.8 mm	Li and Shah [34]
Coriolus versicolor	Methanol	*Staphylococcus epidermidis*, *Staphylococcus aureus*, *Bacillus cereus*, *Listeria monocytogenes*, *Shigella sonnei*, *Yersinia enterocolitica*, *Salmonella ser.* Enteritidis, and *Proteus hauseri*	MIC = 0.625–20.0 mg/mL and MBC = 1.25–40.0 mg/mL	Matijasevic et al. [35]
Lactarius deliciosus	Methanol	*Staphylococcus aureus*, *Bacillus subtilis*, *Bacillus cereus*, *Escherichia coli*, and *Proteus mirabilis*	MIC = 2.5–20.0 mg/mL	Kosanić et al. [36]
Macrolepiota procera	Methanol	*Staphylococcus aureus*, *Bacillus subtilis*, *Bacillus cereus*, *Escherichia coli*, and *Proteus mirabilis*	MIC = 5.0–10.0 mg/mL	Kosanić et al. [36]
Agaricus bisporus, *Pleurotus ostreatus*, and *Lentinula edodes*	Methanol	*Enterococcus faecalis*, *Methicillin sensitive Staphylococcus aureus*, *Methicillin resistant Staphylococcus aureus*, *Escherichia coli*, and *Pseudomonas aeruginosa*	MIC = 0.1–0.2 mg/mL	Taofiq et al. [37]
Verpa bohemica	Butanol and ethyl acetate	*Staphylococcus aureus*, *Escherichia coli*, and *Pseudomonas aeruginosa*	MIC = 250–750 μg/mL and MBC = 500–750 μg/mL	Shameem et al. [38]
Agaricus lanipes	Methanol	*Micrococcus luteus*, *Staphylococcus aureus*, *Bacillus subtilis*, *Proteus vulgaris*, *Escherichia coli*, and *Yersinia enterocolitica*	IZ = 11 ± 0–22 ± 1 mm	Kaygusuz et al. [39]
Lignosus rhinocerotis	Petroleum, chloroform, methanol and aqueous	*Staphylococcus*, *Streptococcus*, *Micrococcus*, *Corynebacterium*, *Bacillus*, *Klebsiella*, *Serratia*, *Salmonella*, *Pseudomonas*, and *Escherichia*	IZ = 7.0–17.67 mm	Mohanarji et al. [40]; Nallathamby et al. [41]

Mushroom	Extracts	Activity against	Method	References
Flammulina velutipes	Ethyl-acetate	*Bacillus cereus, Enterobacter aerogenes, Escherichia coli, Micrococcus luteus, Proteus vulgaris, Salmonella typhimurium*, and *Staphylococcus aureus*	IZ = 7.0 ± 0.10–10.0 ± 0.50 mm and MIC = 2.50 ± 0.5–22.5 ± 1.7 mg/mL	Chaiharn et al. [32]
Ganoderma lucidum	Ethyl-acetate, methanol, aqueous, and ethanol	*Bacillus cereus, Enterobacter aerogenes, Escherichia coli, Micrococcus luteus, Proteus vulgaris, Salmonella typhimurium*, and *Staphylococcus aureus*	IZ = 6.2–20.0 mm and MIC = 1.50–25.0 mg/mL	Chaiharn et al. [32]
Pleurotus ostreatus	Ethyl-acetate, methanol, and ethanol	*Bacillus cereus, Enterobacter aerogenes, Escherichia coli, Micrococcus luteus, Proteus vulgaris, Salmonella typhimurium*, and *Staphylococcus aureus*	IZ = 6.1–12.0 mm and MIC = 1.50–17.5 mg/mL	Chaiharn et al. [32]
Pleurotus pulmonarius	Ethyl-acetate and aqueous	*Bacillus cereus, Enterobacter aerogenes, Escherichia coli, Micrococcus luteus, Proteus vulgaris, Salmonella typhimurium*, and *Staphylococcus aureus*	IZ = 6.1–15.0 mm and MIC = 1.25–15.5 mg/mL	Chaiharn et al. [32]
Leucoagaricus leucothites	Ethanol	*Pseudomonas aeruginosa, Escherichia coli, Enterococcus faecalis*, and *Staphylococcus aureus.*	MIC = 100–400 μg/mL	Sevindik et al. [42]
Craterellus cornucopioides	Acetone	*Bacillus cereus, Bacillus subtilis, Escherichia coli, Proteus mirabilis*, and *Staphylococcus aureus*	MIC = 0.1–0.2 mg/mL	Kosanić et al. [30]
Tricholoma equestre	Aqueous, methanol, cyclohexane, and dichloromethane	*Staphylococcus aureus, Bacillus subtilis, Enterococcus faecalis, Escherichia coli, Klebsiella pneumoniae, Salmonella abony*, and *Pseudomonas aeruginosa*	MIC = 250–500 μg/mL	Muszyńska et al. [43]

MIC-minimum bactericidal concentration; MBC-minimum inhibitory concentration; IZ-inhibition zone (disc diffusion).

Table 1.
Mushroom extracts with antimicrobial activity against Gram-positive and Gram-negative bacteria.

Nowadays, researchers are interested in searching antimicrobial compounds isolated from edible mushrooms that can be useful to inhibit the multidrug-resistant (MDR) pathogens. Recently, Kosanić et al. [30] state that acetone extract of Craterellus cornucopioides has strong minimum inhibitory concentration (MIC) against Gram-positive (Staphylococcus aureus, Bacillus cereus, and Bacillus subtilis) and Gram negative (Escherichia coli and Proteus mirabilis) bacteria with a range of 0.1–0.2 mg/mL. Interestingly, the effect of feeding C57BL/6 mice *Agaricus bisporous* (white button mushroom) was used to feed in mice and to evaluate the bacterial microflora, urinary metabolome, and resistance to a gastrointestinal (GI) pathogen along with control untreated mushroom. As a result, mice treat with mushrooms increased the diversity of the microflora and decreased the GI tract *Clostridia* pathogen [31]. Chaiharn et al. [32] reported that different types of extracts such as ethyl-acetate, methanol, and ethanol and aqueous solvent of *Flammulina velutipes, Ganoderma lucidum*, *Pleurotus ostreatus*, and *Pleurotus pulmonarius* showed significant antibacterial activity against Gram-positive and Gram-negative bacterial pathogens (**Table 1**).

4. Antioxidant potential of edible mushroom

Free radical is unstable and very reactive molecules defined as any molecule containing unpaired electrons. These molecules attack nearby chemical compounds to capture the needed electron for gaining stability [44, 45]. Free radicals can be derivate from nitrogen compounds [Reactive Nitrogen Species (RNS)] or molecular oxygen (O_2) [Reactive Oxygen Species (ROS)]. ROS are the ruling class of radical species producing by endogenous and exogenous sources in living systems [25]. The endogenous source is present in aerobic cells that include metabolism of energy production, respiratory burst, respiratory chain inside the mitochondrial, and some intracellular enzymes reactions. Exogenous sources are tobacco smoke, stress, drugs, environmental pollution, xenobiotics, among others [44, 46].

In physiological conditions, antioxidant compounds control ROS levels by an enzymatic system or a non-enzymatic system. The enzymatic system comprises superoxide dismutase (SOD), glutathione peroxidases, and catalase, whereas ascorbic acid (vitamin C), α tocopherol (vitamin E), glutathione, carotenoids, and flavonoids make part of the non-enzymatic system [45]. However, ROS can be maintained at low concentrations because they require different cell processes, including cell proliferation, apoptosis, and gene expression [46]. The oxidant stress is formed due to in balance of ROS production and antioxidant defenses. The cellular lipids, proteins, and DNA can damage due to increase of ROS that can form various stress like diabetes, cancer, neurological disorders, cardiovascular diseases, mutagenesis, and the aging process [25]. For that reason, the improvement of antioxidant-containing foods may help to reduce the harmful effects caused by oxidative damage [45]. Nowadays, researchers are focused on mushroom antioxidant potential due to their high levels of antioxidants like phenolic compounds, polysaccharides, tocopherols, carotenoids, ergosterol, and ascorbic acid are present in the mushroom [47].

In **Table 2**, we have mentioned various mushroom extracts that have abundant antioxidant activity and produced several phenolic compounds. Total phenolic content varied from 5.1 ± 0.5 to 81.33 ± 1.1 mg GAE/g of extract found in *Boletus edulis* and *Boletus griseipurpureus*, respectively. These compounds can act as oxygen scavengers, peroxide decomposes, and free radical inhibitors as per the various researchers [44, 46]. Additionally, few other compounds like pyrogallol, polysaccharides, flavanols, ascorbic acid, and carotenoid compounds are beneficial for antioxidant potential.

Table 2 shows the phenolic and non-phenolic compound detection based on high-performance liquid chromatography (HPLC), nuclear magnetic resonance

Mushroom	Extracts	Method	Type of compound	Others	Reference
Melaleuca sp.	Ethyl acetate, methanol, and aqueous	TPC, TFC, DPPH, ABTS, FRAP, CUPRAC capacity, phospho-molybdenum, and metal chelating assay	Benzoic acid, p-coumaric acid, p-hydroxybenzoic acid, protocatechuic acid, syringic acid, and trans-cinnamic acid	Similar antioxidant ability among *M. cognata* and *M. stridula*	Bahadori et al. [15]
Agaricus silvaticus Schaeff, Hydnum rufescens Pers., and *Meripilus giganteus (Pers.) Karst*	Methanol and ethyl acetate	TPC, TFC, DPPH, ABTS, FRAP, and catalase activity	Phenolic compounds, flavonoids compounds	Only *H. rufescens* demonstrated activity in DPPH and ATBS assay. The ethyl acetate extract displays strongest antioxidant activity in comparison with methanol extract	Garrab et al. [48]
Tuber indicum	Methanol and ethanol	TPC, TFC, DPPH, and ABTS assay	Phenolic compounds, polysaccharides, flavonoids compounds	Variation in the bioactive substances levels and the antioxidant activity depends on *T. indicum* origins	Li et al. [49]
Lentinus squarrosulus	Aqueous	UND	Phytol, octahydropyrrolo, 1,2-alpyrazine, and 3-trifluoroacetoxy-pentadecane	Among the 15 compounds determinate by GC-MS, three of them possess antioxidant activity	Ugbogu et al. [50]
Tricholoma equestre	Aqueous and methanol	TPC and DPPH	UND	Despite methanol extract was richer in phenols than aqueous extract, both are weak antioxidants	Muszyńska et al. [43]
Agaricus bisporus, Flammulina velutipes, Lentinula edodes, and *Agaricus brasiliensis*	UND	TPC, DPPH, ABTS and FRAP assay	Phenolic, gallic acid, protocatechuic acid, catechol, gentisic acid, p-hydroxybenzoic acid, trans-cinnamic acid, p-coumaric acid, ferulic acid, nonphenolic, fumaric acid, and benzoic acid	*Agaricus* brasiliensis showed the higher phenolic content, and antioxidant activity	Bach et al. [29]
Cantharellus cinereus, Clavariadelphus pistillaris, Clitocybe nebularis, Hygrocybe punicea	Methanol, ethanol and aqueous	TPC, DPPH, ABTS, FRAP, TRP, CUPRAC capacity, and FRS activity	Phenolic compounds	Aqueous extracts exerted better antioxidant activity in comparison with methanol and ethanol extracts	Dimitrijevic et al. [51]

Mushroom	Extracts	Method	Type of compound	Others	Reference
Leucoagaricus leucothites	Ethanolic	DPPH, TOS, TAS, and OSI	Phenolic, gallic acid, catechin, and hesperidin	Ethanolic extracts have powerful antioxidant activity suggesting that can be used as an alternative source of antioxidants	Sevindik et al. [42]
Craterellus cornucopioides	Acetone	TPC, DPPH, superoxide anion, scavenging activity, and reducing power	Phenolic acid, gallic acid, p-coumaric acid, chlorogenic acid, caffeic acid, syringic acid, ferulic acid, flavonols, rutin, quercetin, flavan-3-ol, and catechin		Kosanić et al. [30]
Pleurotus levis, Pleurotus ostreatus, Pleurotus pulmonarius, Pleurotus tuberregium	Hydro-alcoholic	TPC, DPPH assay, ORAC capacity, ABTS assay and β-carotene bleaching	Phenolic components	*Pleurotus ostreatus* showed high antioxidant activity. The correlation between TPC and ATBS assay indicated that phenols are the major antioxidant components	Adebayo et al. [52]
Flammulina velutipes, Ganoderma lucidum, Pleurotus ostreatus, Pleurotus pulmonarius	Hexan, ethylacetate, ethanol, methanol, and aqueous	ABTS assay and TEAC	Polysaccharides	*Ganoderma lucidum* possess the higher antioxidant potential in comparison with the other 3 evaluated mushrooms	Chaiharn et al. [32]
Amanita sp., *Lactarius volemus*, *Russula* sp., *Termitomyces* sp., *Tricholoma crissum*, *Volvariella volvácea*, *Astraeus hygrometricus*, *Alpova trappei, Auricularia auricula, Cantharellus cibarius, Cra Craterellus aureus, and Lentinus* sp.	Methanol	TPC, TFC, DPPH, and FRAP	Flavonols, quercetin, quercetin-3-O-rutinoside, myricetin, kaempferol, flavan-3-ols, catechin, epicatechin, flavanone, and naringenin	*T. clypeatus* and *V. volvacea* show the highest antioxidant activity and the highest concentrations of phenolic compounds. Despite, these two mushrooms can be included in the diet, it is needed more studies to determine if it can be used as a food supplement	Butkhup et al. [53]

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Mushroom	Extracts	Method	Type of compound	Others	Reference
Macrocybe lobayensis	Hydro ethanol	TPC, DPPH assay, ABTS assay, superoxide radical, hydroxyl radical quenching chelating ability of metal ion, reducing power, and TAC	Ferulic acid, cinnamic acid, pyrogallol, flavonoid, ascorbic acid, β-carotene, and lycopene	The obtained hydro-ethanol extract was enriched with bioactive compounds and exhibited strong antioxidant potentiality	Khatua et al. [54]
Boletus edulis, Boletus pinophilus, Boletus aureus, Armillaria mellea, Tuber aestivum, Lactarius piperatus, Lactarius deliciosus, Pleurotus eryngii, Ramaria botrytis, and *Russula virescens*	Ethanol	DPPH assay, chelating activity, reducing power, and inhibition of lipid peroxidation	Caffeic acid, gallic acid, 3,4 and 2,5 dihydroxybenzoic, cinnamic acid, phenols, flavonoids, flavonols, anthocyanins, proanthocyanidins, ascorbic acid, lycopeneand, and β-carotene	Polysaccharide compound was correlated with DPPH assay activity. Phenolic compounds were correlated with the reducing power, and the inhibition of lipid peroxidation	Vamanu [55]
Pleurotus ostreatus	UND	DPPH and ABTS assay	Three them were new amino acid derivatives	These three new compounds: (1) $C_{12}H_{14}N_2O_4$, (2) $C_9H_{16}N_2O_4$, and (3) $C_{12}H_{12}N_4O_3$ have comparable antioxidant activity with that of the standard compound	Lu et al. [56]
Agaricus lanipes	Methanol	TPC, TAC, TOS, LOOHs, and TFS	UND	This is the first report of the antioxidant activity of *Agaricus lanipes*	Kaygusuz et al. [39]
Agaricus bisporus and *Ganoderma lucidum*	Aqueous	DPPH assay	Flavonoids and carboxylic acids	*A. bisporus* silver nanoparticles possess the highest antioxidant ability	Sriramulu and Sumathi [57]
Agaricus lanipes	Methanol	TPC, TAC, TOS, LOOHs, and TFS	UND	This is the first report of the antioxidant activity of *Agaricus lanipes*	Kaygusuz et al. [39]
Ramaria subalpine	Methanol	TPC, TFC, ascorbic acid content, ß-carotene and lycopene content, DPPH, ferrous ion chelating, and reducing power	Pyrogallol	This edible mushroom showed potentiality in the antioxidant activity assays. Otherwise, phenolic compounds were the major bioactive component founded	Acharya et al. [58]

Mushroom	Extracts	Method	Type of compound	Others	Reference
Agaricus campestris and *Boletus edulis*	Methanol	Total soluble phenolic compounds, TPC, DPPH assay, and reducing power	Phenolic compounds	Despite *B. edulis* possess higher antioxidant activity than *A. campestris*, both can be an alternative for antioxidant sources	Kosanić et al. [59]
Boletus griseipurpureus	Dichloromethane and methanol	TPC, DPPH, oxygen radical absorbance, ORAC, and ABTS assay	Phenolic compounds	*Boletus griseipurpureus* extracts showed similar antioxidant activity to other *Boletus* species as previous studies	Sudjaroen and Thongkao [60]

UND-undetermined; TPC-total phenolic content; TFC-total flavonoids content; FRAP-ferric reducing antioxidant power; CUPRAC-cupric reducing antioxidant capacity; TRP-total reducing power; FRS-determination of free radical scavenging; TOS-total oxidant status; TAS-total antioxidant status; OSI-oxidative stress index; TEAC-trolox equivalent antioxidant capacity; ORAC-oxygen radical absorbance capacity; TAC-total antioxidant capacity; LOOHs-lipid hydroperoxides; TFS-total free sulfhydryl group.

Table 2.
Studies on antioxidant activity in edible mushroom.

(NMR) analysis, chromatographic method or gas chromatography–mass spectrometry (GC–MS). Moreover, **Table 2** described that the different kinds of mushrooms could be used to determine the antioxidant activity potential in several ways, such as 1,1-diphenyl-2-picrylhydrazyl (DPPH), 2,2′-azinobis-(3-ethylbenzthiazoline-6-sulphonate (ABTS), and ferric-reducing antioxidant power (FRAP). Further, Sriramulu and Sumathi [57] demonstrated that extract of edible *Agaricus bisporus* and wild *Ganoderma lucidum* mushroom was used to synthesize silver nanoparticles that showed photocatalytic activity and biological activities such as in vitro antioxidant activity, anti-inflammatory activity, and antimicrobial activity against bacterial pathogens such as *E. coli* and *S. aureus*. Garrab et al. [48] reported that ethyl acetate extract of *Agaricus silvaticus* Schaeff., *Hydnum rufescens* Pers., and *Meripilus giganteus* (Pers.) Karst. exhibited antioxidant and anticholinesterase activity. Interestingly, ethyl acetate extract of *Hydnum rufescens Pers.* indicated the highest antioxidant activity in DPPH and catalase potential. Recently, many researches are focusing on extracting the compound like chitosan and chitosan + procyanidin obtained from a mushroom that can be used to coat the blueberries, which revealed the higher antioxidant potential as compared to no coated berries [61]. Similarly, Velez et al. [62] reported that AA-loaded chitosan/tripolyphosphate nanoaggregates obtained from mushrooms, which can be useful to coat the fresh-cut mushrooms that displayed significant antioxidant activity. Moreover, some studies had reported that antioxidant activity, total phenolic compounds, and total flavonoid compounds increased in tarhana and bread after the addition of *Morchella conica*, *Ramaria flava,* and *Agaricus bisporus* powder [16, 17].

In addition, some researchers are investigated to study the antiangiogenic potential to prevent neurological disorders and hepatoprotective properties. A p-terphenyl compound is derived from two edible mushrooms that showed the anticancer effect to averts vascular endothelial growth factor with the presence of antioxidant and anti-inflammatory activity [63]. Few researchers reported that benzoic acid derivative compounds such as be p-hydroxybenzoic, protocatechuic, gallic, gentisic, homogentisic, vanillic, 5-sulphosalicylic, syringic, veratric, and vanillin obtained from diverse types of much room such as *Phellinus rimosus, Ganoderma lucidum, Ganoderma tsugae, Coriolus versicolor, Lentinus edodes, Volvariella volvacea, Termitomyces heimii, Helvella crispa, Termitomyces tylerance, Lactarius sanguifluus, Morchella conica, Termitomyces mummiformis, Pleurotus sajor-caju, Termitomyces schimperi, Lentinus squarrulosus, Boletus edulis, Pleurotus djamor, Macrolepiota procera, Cantharellus clavatus, Morchella angusticeps,* and *Termitomyces microcarpus* [25]. Recently, a few different polyphenols like curcumin, resveratrol, and quercetin showed pro-oxidant activity that can act as photosensitizers to produce $1O_2$ as per Lagunes and Trigos [64]. Additionally, Li et al. [65] reported that the aqueous extract of *Amanita caesarea* was estimated in an L-glutamic acid to induce the HT22 cell apoptosis model. In contrast, D-galactose and $AlCl_3$ have improved Alzheimer's disease (AD) in the mice model to prevent neurogenerative diseases. One of the interesting studies Chen et al. [66] explored is that polysaccharides isolated from *Grifola frondosa* could be used to improve memory impairment in aged rats by increasing total antioxidant capacity, glutathione peroxidase activity, superoxide dismutase activity, and catalase activity. Dong et al. [67] indicated that enzyme-assisted *M. esculenta* polysaccharide enhances hepatic antioxidant enzymes that can decrease the amount of lipid peroxidation in mice models.

5. Conclusion and concluding remarks

Mushroom is widely useful as food supplements and suitable for all the age groups due to their high content of protein, dietary fiber, vitamins, and mineral. Moreover, they contain various bioactive molecules such as polysaccharides, terpenoids, glycoproteins, antimicrobial compounds, antioxidants, etc. that can play a major role in the treatment of numerous diseases like improving immune strength, decreasing the cancer level in the body, reducing blood sugar level, inhibiting the multidrug resistant bacterial pathogen, and many more. In this review, we have focused on antioxidant and antimicrobial activity of edible and non-edible mushrooms all over the world and their uses. We have found that few of the mushroom are producing wide variety of bioactive phenolic compounds such as pyrogallol, polysaccharides, flavanols, ascorbic acid, and carotenoid compounds that can be used to control various diseases like antitumor, antimicrobial, antioxidant and anti-hypertensive, hypocholesterolemic, and hepatoprotective activity. Mushrooms like *Agaricus silvaticus Schaeff, Hydnum rufescens Pers., Meripilus giganteus (Pers.) Karst.*, *Termitomyces sp. Tricholoma crissum, Volvariella volvácea, Astraeus hygrometricus, Alpova trappei, Auricularia auricula, Cantharellus cibarius, Cra Craterellus aureus, Lentinus sp.*, etc. showed significant antioxidant activity and produced various compounds that detected by HPLC, GC-MS, and NMR spectroscopy as presented in the tables. Further, different solvent extracts of *Xerocomus ichnussanus, Boletus lupinus, Flammulina velutipes, Phellinus igniarius, Sarcodon imbricatus, Tricholoma aurantium, Agaricus bisporus, Pleurotus ostreatus, and Lentinula edodes* exhibited potent antimicrobial activity against Gram-positive and Gram-negative bacteria as shown in the table. It can be concluded that mushroom has high therapeutic potential that could be used for the development of new formulations, which can be beneficial for new nutraceutical products. Hence, new methods should be used to isolate novel compounds from different mushrooms that can be used for the deterrence and decrease of several diseases.

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Conflict of interest

The authors declare that no conflict of interest for this publication.

Author details

Maria Paula Gómez Román[1†], Nathalia Badillo Mantilla[1†], Sergio Andrés Carreño Flórez[1], Surajit De Mandal[2], Ajit Kumar Passari[1*†], Beatriz Ruiz-Villáfan[1], Romina Rodríguez-Sanoja[1] and Sergio Sánchez[1*]

1 Instituto de Investigaciones Biomédicas, Universidad Nacional Autónoma De México, Ciudad de México, Mexico

2 College of Agriculture, South China Agricultural University, Guangzhou, P.R. China

*Address all correspondence to: ajit.passari22@iibiomedicas.unam.mx and sersan@biomedicas.unam.mx

† These authors contributed equally to this work.

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